Pergamon

Tetrahedron Letters 39 (1998) 647–650

TETRAHEDRON LETTERS

Reverse Regioselective Photosensitized Nucleophilic Addition of Arylcyclopropanes

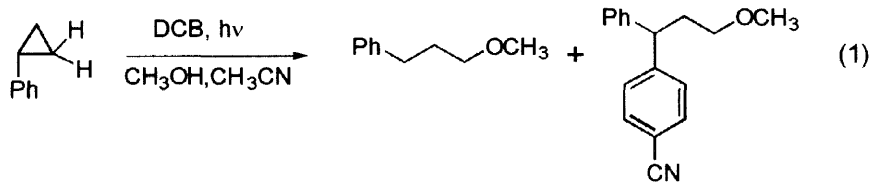
Jin-Yi Wu, Jing-Chen Mai, Kai Pan and Tong-Ing Ho*

Department of Chemistry National Taiwan University, Taipei, Taiwan, R. O. C.

Received 4 October 1997; revised 19 November 1997; accepted 21 November 1997

Abstract: Reverse regioselective nucleophilic addition of 1-aryl-2,2-dichlorocyclopropanes (**1-7**) photosensitized by 1,4-dicyanobenzene (DCB) has been observed to give 1-aryl-1-methoxy-3,3-dichloropropanes (for methanol) as the only regioselective products.

Regioselective photochemical reactions are important.[1] Phenylcyclopropanes are photochemically active under direct photolysis[2-3] or when using an electron-poor photosensitizer.[4-8] Rao and Hixson[7] have reported the photosensitized regioselective nucleophilic addition of arylcyclopropanes with methanol (eq. 1).

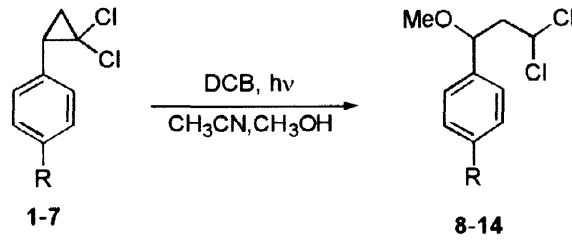


(1)

It has been suggested that this reaction arises from nucleophilic addition at the electropositive site of ring-closed cyclopropane cation radical. Further studies[4] have revealed that the arylcyclopropane radical cations undergo stereospecific nucleophilic substitution with complete inversion of configuration.

Direct irradiation of compounds **1-7** at > 280 nm led to the recovery of the starting material. When **1-7** were photolyzed using 1,4-dicyanobenzene (DCB) as sensitizer at 300 nm in acetonitrile-methanol (12:1) solution at room temperature, the isolated products were 1-aryl-1-methoxy-3,3-dichloropropanes **8-14** (Scheme 1).[10] Most of the incident light was absorbed by DCB when irradiated with 300 nm light. The DCB was recovered after irradiation. The isolated yields for the regioselective methanol addition products **8-14** are based on the recovered starting materials and are listed in Table 1. It is interesting to observe that methanol attacks the C-1 of the cyclopropane rings of compounds **1-7** independent of the type of substituents at the para position of the phenyl ring.

0040-4039/98/$19.00
PII: S0040-4039(97)10708-0



R = **1**, **8**, OCH_3 **2**, **9**, $CH(CH_3)_2$ **3**, **10**, CH_3
4, **11**, H **5**, **12**, F **6**, **13**, Cl
7, **14**, CN

Scheme 1

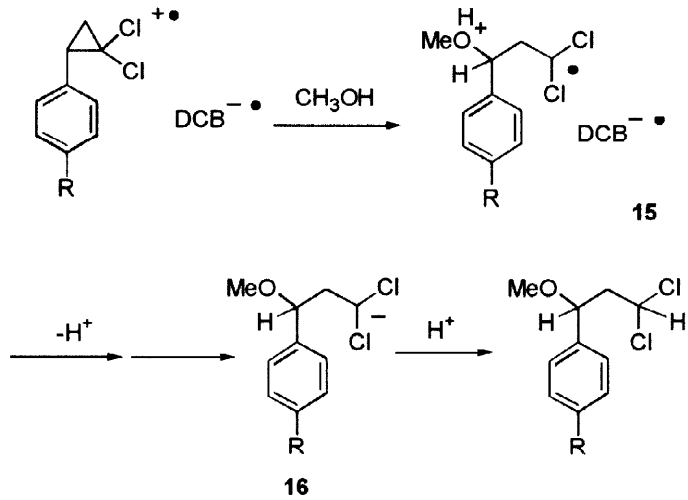
From the negative free energy change (Table 1) it is plausible that the cation radicals of the 1-aryl-2,2-dichlorocyclopropane (**1-7**) were generated by electron transfer from **1-7** to the excited singlet state of DCB. Thus C-1 of the cation radicals of **1-7** bears a positive charge. The presence of two chlorine atoms at the C-2 carbon prevents the nucleophilic attack of methanol, which reverse the regiochemistry as compared to the previous results.[7]

Table 1. Oxidation Potentials ($E_{1/2}$ox(V)) and Free Energy Changes for Electron Transfer (ΔG) for Compounds **1-7** and Isolated Yields for Products **8-14**.

Reactant	Eox(V) [a]	ΔG [b] (eV)	Product	Irradn. time (h)	Conversion (%)	Yield (%)	Recov. of DCB (%)
1	1.53	-1.07	**8**	4	43	18	99
2	1.78	-0.82	**9**	5	27	21	91
3	1.77	-0.83	**10**	6	13	71	85
4	1.88	-0.72	**11**	9	23	85	99
5	1.89	-0.72	**12**	6	31	22	99
6	1.89	-0.71	**13**	6	19	88	88
7	2.20	-0.40	**14**	9	24	17	96

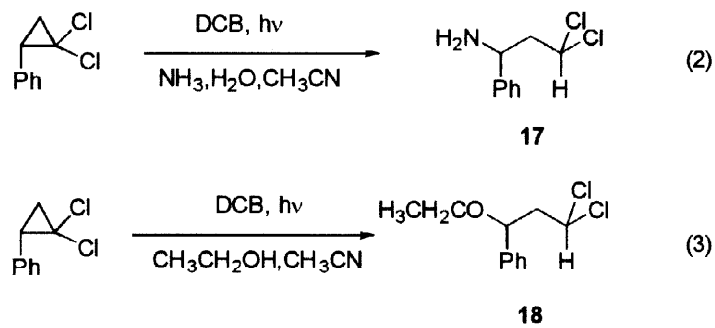
a. Half-peak oxidation potentials vs. $Ag/AgNO_3$ in CH_3CN.
b. Calculated from the oxidation potentials using Rehm-Weller Equation.[11]

Nucleophilic attack by methanol on the radical cations of **1-7** leads to the formation of an ring-opened cation radicals **15** (Scheme 2), with the radical center located at the C-3 adjacent to the two chlorine atoms. The radical stabilization energies calculated for one chlorine atom are ranged from +2.4 to +2.6 kcal/mole for the substituted methyl radicals.[9] Reverse electron transfer from DCB anion radical to the radical site of **15** to generate **16** is fast due to two chlorine atoms. Thus dimerization of cation radical **15** is not observed in contrast to the observation of Mizuno *et al.*,[6] they isolated the methanol-adduct as well as 1,6-dimethoxy-3,4-diphenylhexane as the dimer.



Scheme 2

We have studied other nucleophiles such as ammonia[12] (eq. 2) and ethanol[13] (eq. 3) and it is also found to attack the C-1 site of the cation radical of 1-phenyl-2,2-dichlorocyclopropane.



In conclusion, the presence of two chlorine atoms at C-2 position of **1-7** can reverse the regioselectivity of the nucleophilic addition of the photosensitized reaction completely. The C-1 position of the cation radicals of **1-7** apparently bears the positive charge thus nucleophilic attack at this position is more favored in contrast to the phenylcyclopropane system in which C-2 position is attacked by nucleophiles.

References and notes

1. (a) Ho, T. I. and Chow, Y. L., In *Supplement F2: The chemistry of amino, nitroso, nitro and related groups*, Patai, S. and Rappoport, Z., Eds.; John Wiley and Sons: Chichester, 1996; Part 2, Chapter 15.

(b) Yasuda, M.; Isami, T.; Kubo, J.; Mizutani, M.; Yamashita, T.; Shima, K. *J. Org. Chem.* **1992**, *57*, 1351-54.

2. Hixson, S. S.; Franke, L. A. *J. Org. Chem.* **1988**, *53*, 2706-11.

3. Zimmerman, H. E.; Heydinger, J. A. *J. Org. Chem.* **1991**, *56*, 1747-58.

4. Dinnocenzo, J. P.; Simpson, T. R.; Zuilhof, H.; Todd, W. P.; Heinrich, T. *J. Am. Chem. Soc.* **1997**, *119*, 987-93.

5. Mazzocchi, P. H.; Somich, C.; Edwards, M.; Morgan, T.; Ammon, H. L. *J. Am. Chem. Soc.* **1986**, *108*, 6828-29.

6. Mizuno, K.; Ogawa, J.; Otsuji, Y. *Chem. Lett.* **1981**, 741-44.

7. Rao, V. R.; Hixson, S. S. *J. Am. Chem. Soc.* **1979**, *101*, 6458-59.

8. Wong, P. C.; Arnold, D. R. *Tetrahedron Lett.* **1979**, 2101-04.

9. Bordwell, F. G.; Zhang, X.-M.; Alnajjar, M. S. *J. Am. Chem. Soc.* **1992**, *114*, 7623-29.

10. Spectral data for **8**: ^{1}H NMR ($CDCl_3$) δ 7.13-7.19 (m, 2H), 6.82-6.86 (m, 2H), 5.79 (dd, J = 9.1, 4.4 Hz, 1H), 4.24 (dd, J = 9.5, 4.1 Hz, 1H), 3.75 (s, 3H), 3.11(s, 3H), 2.58 (ddd, J = 13.6, 9.5, 4.4 Hz, 1H), 2.28 (ddd, J = 13.6, 9.1, 4.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 159.6, 131.9, 127.9, 114.1, 79.9, 70.8, 56.5, 55.3, 51.9; EI-MS (70 ev) *m/z* 250 (M^++2, 7.5), 248 (M^+, 9), 151 (100). **9**: ^{1}H NMR ($CDCl_3$) δ 7.28 (s, 2H), 7.24 (s, 2H), 5.90 (dd, J = 9.2, 4.0 Hz, 1H), 4.35 (dd, J = 9.5, 4.0 Hz, 1H), 3.30 (s, 3H), 2.85 (sept, J = 7.0 Hz, 1H), 2.66 (ddd, J = 13.5, 9.5, 4.0 Hz, 1H), 2.40 (ddd, J = 13.5, 9.2, 4.0 Hz, 1H), 1.27 (d, J = 7.0 Hz, 6H); ^{13}C NMR ($CDCl_3$) δ 148.9, 137.2, 126.8, 126.5, 80.1, 70.8, 56.7, 51.9, 33.8, 23.9; EI-MS (70 ev) *m/z* 260 (M^+, 2), 163 (100), 148 (12). **10**: ^{1}H NMR ($CDCl_3$) δ 7.18 (s, 2H), 7.12 (s, 2H), 5.80 (dd, J = 9.2, 4.2 Hz, 1H), 4.26 (dd, J = 9.5, 4.0 Hz, 1H), 3.13 (s, 3H), 2.56 (ddd, J = 13.5, 9.5, 4.0 Hz, 1H), 2.34 (s, 3H), 2.28 (ddd, J = 13.5, 9.2, 4.2 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 138.0, 136.9, 129.4, 126.5, 80.1, 70.8, 56.6, 51.9, 21.1; EI-MS (70 ev) *m/z* 234 (M^++2, 2), 232 (M^+, 3.5), 135 (100), 91 (18). **11**: ^{1}H NMR ($CDCl_3$) δ 7.41-7.24 (m, 5H), 5.90 (dd, J = 9.4, 4.2 Hz, 1H), 4.37 (dd, J = 9.6, 3.9 Hz, 1H), 3.21 (s, 3H), 2.64 (ddd, J = 13.5, 9.6, 4.2 Hz, 1H), 2.38 (ddd, J = 13.5, 9.4, 3.9 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 140.0, 128.7, 128.2, 126.5, 80.3, 70.7, 56.7, 51.9; EI-MS (70 ev) *m/z* 218 (M^+, 0.5), 121 (100). **12**: ^{1}H NMR ($CDCl_3$) δ 7.31-6.95 (m, 4H), 5.82 (dd, J = 9.2, 4.2 Hz, 1H), 4.28 (dd, J = 9.6, 4.0 Hz, 1H), 3.13 (s, 3H), 2.53 (ddd, J = 13.5, 9.6, 4.2 Hz, 1H), 2.25 (ddd, J = 13.5, 9.2, 4.0 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 140.0, 128.3, 126.6, 115.5, 79.7, 70.5, 56.8, 51.9. **13**: ^{1}H NMR ($CDCl_3$) δ 7.26-7.30 (m, 2H), 7.15-7.19 (m, 2H), 5.81 (dd, J = 9.3, 4.0 Hz, 1H), 4.28 (dd, J = 9.6, 3.8 Hz, 1H), 3.13 (s, 3H), 2.53 (ddd, J = 13.4, 9.6, 4.0 Hz, 1H), 2.25 (ddd, J = 13.4, 9.3, 3.8 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 138.6, 134.0, 128.9, 127.9, 79.7, 70.4, 56.8, 51.9; EI-MS (70 ev) *m/z* 254 (M^++2, 1), 252 (M^+, 0.8), 155 (100), 91 (9). **14**: ^{1}H NMR ($CDCl_3$) δ 7.68-7.64 (m, 2H), 7.44-7.40 (m, 2H), 5.89 (dd, J = 9.6, 3.7 Hz, 1H), 4.42 (dd, J = 9.9, 3.6 Hz, 1H), 3.21 (s, 3H), 2.50 (ddd, J = 13.3, 9.9, 3.7 Hz, 1H), 2.35 (ddd, J = 13.3, 9.6, 3.6 Hz, 1H).

11. Rehm, D.; Weller, A. *Isr. J. Chem.* **1970**, *8*, 259-71.

12. **17**: ^{1}H NMR ($CDCl_3$) δ 7.41-7.37 (m, 5H), 5.92 (dd, J = 9.2, 3.8 Hz, 1H), 4.96 (dd, J = 9.5, 3.8 Hz, 1H), 2.66 (ddd, J = 13.2, 9.2, 3.8 Hz, 1H), 2.47 (ddd, J = 13.2, 9.5, 3.8 Hz, 1H).

13. **18**: ^{1}H NMR ($CDCl_3$) δ 7.32-7.20 (m, 5H), 5.93 (dd, J = 9.4, 3.9 Hz, 1H), 4.47 (dd, J = 9.7, 3.8 Hz, 1H), 3.47-3.25 (m, 2H), 2.62 (ddd, J = 13.5, 9.7, 3.9 Hz, 1H), 2.36 (ddd, J = 13.5, 9.4, 3.8 Hz, 1H), 1.16 (t, J = 7.0 Hz, 3H).